European security of electricity supply policy in the context of increasing volumes of intermittent generation

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Abstract

In response to plans in France and the UK to implement a capacity mechanism and the recent implementation of a small strategic reserve in Germany, we address the question of the cross-border effects of national implementation of a capacity mechanism in Europe's interconnected markets. We model some of the effects that may arise when different countries implement different types of capacity mechanisms. We draw conclusions with respect to generation adequacy policy in Europe.

Capacity markets appear to be more effective than strategic reserve in attracting investment and securing supply in the long run, but may discourage investment in neighboring countries. A strategic reserve is easier to implement and does not have this negative externality, but its dynamic effectiveness is less certain and its effect may leak away across the border.

The negative externality of a capacity mechanism may put pressure on neighboring countries to also implement a capacity mechanism. However, the proliferation of different types of capacity mechanisms – every category of capacity mechanism can be implemented in a myriad of different ways – creates a significant risk trade between countries will be increasingly distorted. Considering also the regulatory uncertainty that is brought about by this process and the risk of regulatory failure with implementing the more sophisticated capacity mechanisms such as capacity markets and reliability options, the positive effect on investment is not a given.

Keywords: electricity, generation, capacity mechanism, security of supply.

1 Introduction

An increasing number of countries in Europe is implementing a capacity mechanism (a policy instrument for ensuring an adequate level of electricity generation capacity). Scandinavian countries and Poland have some form of a strategic reserve, Ireland and several Mediterranean countries have different kinds of capacity payments, and now France and the UK are in the process of developing different types of capacity markets. In the remaining countries with energy-only markets, this raises the questions of what the impact on their markets and whether they should also implement a capacity mechanism.

The renewed interest in capacity mechanisms – there was a debate about their need a decade ago, following the power crisis in California – is driven in part by the realization that increasing volumes of intermittent energy sources (mainly wind and solar power) will not decrease the need for thermal generation capacity by much in systems without much storable hydropower, but will reduce the operating hours of those thermal plants. In this paper, we analyze the arguments for and against introducing capacity mechanisms in European electricity markets. We focus on the practical complications that arise when different countries implement different types of capacity mechanisms by modeling the effects of a capacity mechanism in one country on a neighboring country without or with a different a capacity mechanism. We draw conclusions with respect to generation adequacy policy in Europe.

2 Three discussions

In the current debate about capacity mechanisms in Europe, three elements come together. The first is the discussion about whether a capacity mechanism is needed at all. In theory, energy-only electricity markets – markets in which electricity prices provide the only investment incentive – should provide optimal incentives for investment (cf. Caramanis, 1982; Stoft, 2002). In practice, however, the many of the conditions for this theory to hold are not met:

- Consumers as well as producers may be risk-averse;
- Producers do not have sufficient information, in part because fundamental changes in the electricity market restrict the possibility of making forecasts;
- There is regulatory uncertainty, e.g. with respect to CO_2 policy, renewable energy policy and fuel policy;
- Price restrictions, such as a maximum price, may apply;
- There may be restrictions to investment, e.g. due to land-use regulations or public opposition.

Due to these factors there appears to be a risk of insufficient investment, which, as a consequence of the long lead times of new generation facilities, might develop into an investment cycle (e.g. Ford, 1999).

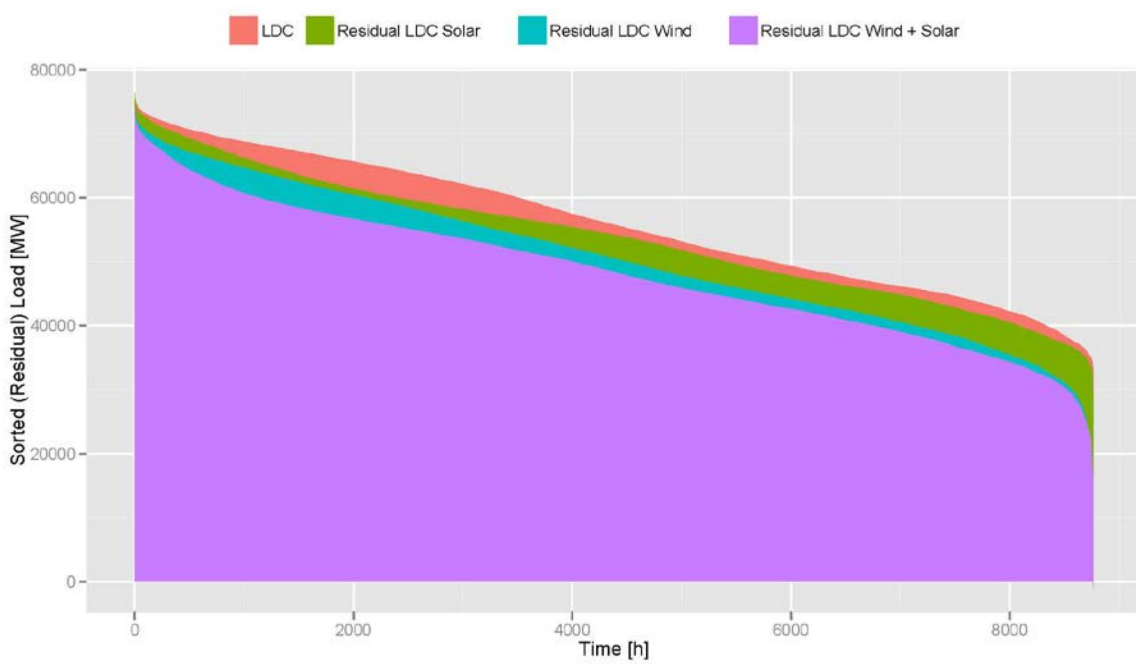

Figure 1: Estimated load duration curve for Germany, and the residual curve (purple) after subtracting solar and wind energy production. Load-duration data is based on ENTSO-E (2011) and renewable energy production data was based on data from 50Hertz Transmission GmbH of actual Photovoltaic and Wind generation.

A number of European energy-only markets have functioned without serious shortages so far, which has supported confidence in this market design. However, with the UK developing a version of reliability options and France considering the implementation of a capacity market (U.K. Department of Energy and Climate Change, 2011), the volume of Europe's energy-only markets is shrinking significantly. This implementation of a capacity mechanism in the UK confronts the remaining energy-only markets with the question that if, after a thorough analysis, the first and most ardent protagonist of competition in electricity arrives at the conclusion that an energy-only market will probably not provide adequate investment incentives, why would the other energy-only markets in Europe be expected to perform better?

The empirical evidence is clouded by public ownership of generation companies and market concentration. In most of the USA, capacity markets have been implemented. The only state without a capacity mechanism, Texas, experienced a shortage during a heat wave in 2011. In Europe, there are more countries without capacity mechanisms. Of these, only the UK is concerned about a generation shortage (U.K. Department of Energy and Climate Change, 2011). In other countries such as France, Germany, the Netherlands, Belgium, Austria and Hungary, investment appears to have been adequate. (According to ENTSO (2012a), the reserve margin in Germany will become slim by the end of this decade, but the nuclear phase-out contributes to this.) Without clear empirical evidence of the need for a capacity mechanism, the debate is still unsettled, but the discussions intensified with the decisions of the UK and France to implement (different types of) capacity markets in 2011 (U.K. Department of Energy and Climate Change, 2011; Legifrance, 2012). The second aspect is that with increasing volumes of intermittent generation, the residual load-duration curve – the load that needs to be served by thermal plant – becomes lower on average, while the peak does not decrease nearly as much. Figure 1 illustrates the effect for the German market (if interconnection capacity is not taken into account). As off-peak prices will drop, peak prices will need to increase if the same volume of thermal plant is to be maintained. Increased price volatility is therefore the inevitable corollary of an increase in intermittent energy sources. (The data in Figure 1 was extrapolated from the 50Hertz area to the whole of Germany, which means that wind energy is over represented and solar energy is under represented. The essence of is the same, however: wind and solar cause the demand for off-peak generation capacity to decline faster than the demand for peak capacity.)

In theory, this should not affect investment, if the energy companies can continue to model expected electricity prices with sufficient accuracy and if they are not risk-averse. However, the effects of the imperfections of real markets on investment are exacerbated by higher price volatility. Forecasting the revenues of thermal power generators will become even more difficult than it already is, as they become increasingly dependent on infrequent but high price spikes. If investment in generation capacity is slightly higher than optimal, or if demand growth is slightly lower than expected, this may already cause peak prices to be deflated for an extensive period, causing average prices to fall below cost. Larger business cycles, such as the decrease in demand after 2008, could cause prolonged periods during which generation companies could not recover their costs. The uncertainties that characterize the decarbonization pathway, from technological development to future policy changes, cause a permanently high level of investment risk. Thus the presence of a significant volume of renewable energy sources may undermine the very goal for which they were installed: the decarbonization of the power sector. By increasing the volatility of electricity prices they increase investment risk, which will discourage investment in capital-intensive generation technologies.

Consumers tend to be risk-averse and prefer a slightly higher electricity price over periodic episodes with very high prices, even if in the latter case the long-term average price is lower. Politically, periods with high electricity prices are also unattractive because they suggest that energy policy is failing, even if the high prices can be considered economically efficient. Because the social cost of electricity shortages is much higher than the cost of a modest level of excess generation capacity (cf. Cazalet et al., 1978), from a social point of view a capacity mechanism appears attractive. The risk of creating excess generation capacity can be considered as a social insurance against the much higher social cost of power shortages.

The third aspect of the current discussions in Europe is that the proliferation of different types of capacity mechanisms in Europe reduces the transparency of the internal market and capacity mechanisms may have external effects on neighboring markets. It is this latter effect that we would like to explore more in depth, in particular the questions of what the effects are on generation adequacy and prices if one country implements a capacity mechanism and the other does not. In the next section we will introduce a simple model that we developed in order to test the possible effects.

3 Model

3.1 Purpose

A static equilibrium model of supply and demand in two interconnected countries was developed in Excel 2010 in order to explore the short-run cross-border effects of different generation adequacy policies on wholesale electricity prices and hence on consumer and producer surplus. This provides a first impression of the effects on reliability and investment. The model was developed to assess the cross-border effects of different generation adequacy policies in the Netherlands, France and Germany on the Netherlands, but the conclusions can be extrapolated to other combinations of countries, as the nature of the effects can be expected to be the same.

The model facilitates a pair-wise comparison of countries and policy instruments. Because France is developing plans to implement a capacity market and Germany has a (temporary and small) strategic reserve, we assessed the following combinations of generation adequacy policy:

- A strategic reserve in Germany and an energy-only market in the Netherlands (Section 4.1);
- A capacity market in France in combination with an energy-only market in the Netherlands (Section 4.2);
- A capacity market in France in combination with a strategic reserve in the Netherlands (Section 4.3).

The latter scenario was included because in 2005 the Netherlands developed plans for a strategic reserve but postponed implementation indefinitely as there was no apparent need. As this option is still available, this is a likely choice of capacity mechanism if the Netherlands is to implement one.

Table 1: Exploratory scenarios of electricity consumption employed in the simulation

Scenario	Country 1	Country 2
1	Low	Low
2	Low	High
3	High	Low
4	High	High

Per set of generation adequacy policies, we analyzed the four 'what if' scenarios that are outlined in in Table 1. Each set of scenarios is run with the implementation of a capacity mechanism as described above and, as a counterfactual, without any capacity mechanisms.

3.2 Supply and demand

Generators are assumed to bid at their marginal cost of production, which is modeled as the fuel cost of electricity production for 2010. Strategic behavior – such as abuse of market power – is not considered, even though it may present a significant risk, because the object here is to analyze cross-border effects that would occur under the best of conditions. The supply functions are stylized. For each fuel source, fuel costs are taken from the cost estimations made by IEA (2010). However, since this source does not include oil and biomass, these fuel costs were calculated differently. Fuel efficiencies for oil and biomass units were taken from Blesl et al. (2006) and fuel prices of oil and biomass are taken respectively from OPEC (2010) and VGB (2011). Other associated costs such as start-up and shutdown are neglected. Lastly, actual generation portfolios are fixed values, which were taken from Eurelectric (2012) for the year 2010 as they are the most recent source.

The load-duration curves are based on data from ENTSO-E (2012b) for 2010. This data provides 24 hourly demand realizations for a representative day for each month of the year. From these 12 x 24 data points, a load-duration curve was created by fitting a polynomial through them. These smoothed load-duration curves were divided into 14 sections. The model was run for the average load during each of these 14 sections. The sections were not equally wide: narrower sections were used around the peak of the load-duration curve because peak hours are key to the issue of generation adequacy. Demand is the independent variable which is used to clear the markets.

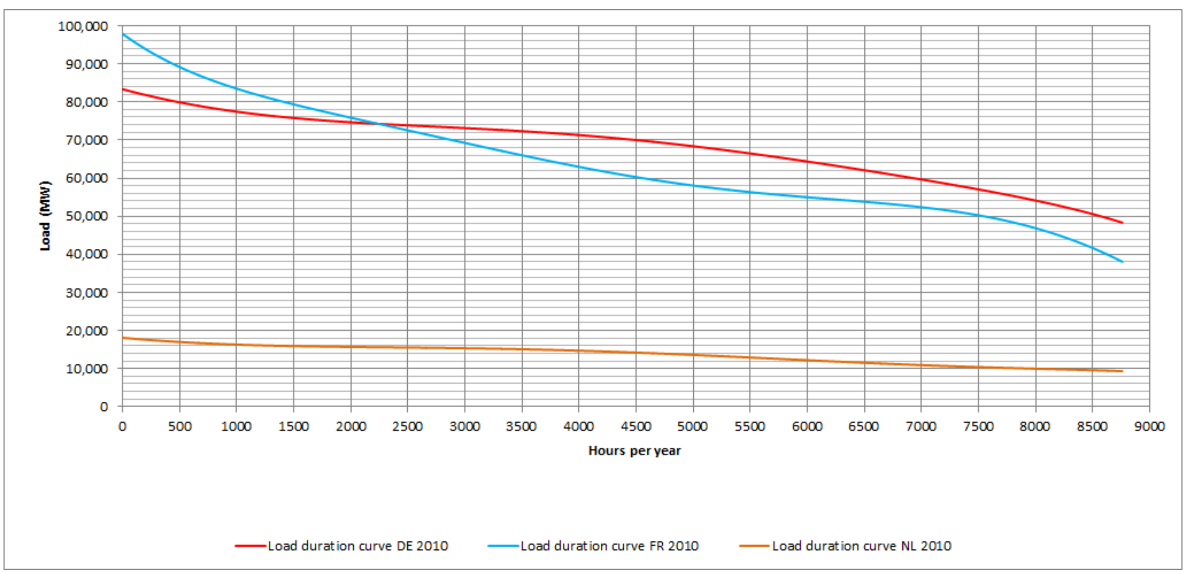

Figure 2: Fitted load duration curves used as to simulate different levels of electricity consumption in the model

In cases when demand exceeded supply, a maximum price of 3000 €/MWh was used. This is the maximum price of the Amsterdam Power Exchange (APX) and we assume that prices in the Netherlands and neighboring countries will not rise significantly higher for a significant amount of time. While it is true that the value of lost load is estimated at 8600 €/MWh (De Nooij et al., 2003) for the Netherlands (and different estimates exist for other countries), the lower value of 3000 €/MWh was taken because this price applies to all of the top 50 hours of the load-duration curve.

3.3 Interconnector congestion management

Each country is represented as a single node; it is assumed that cross-border network constraints are handled through an idealized representation of market coupling. The following steps are the basis for the market clearing and market coupling algorithm:

1. Determine the merit order of supply in both countries.
2. Choose the specific value of electricity demand for the 14 simulation demand values taken from the load duration function.
3. Clear the two markets independently (as if there is no interconnection capacity).
4. Buy electricity from the lower-priced market up to the point that either the electricity prices converge or the interconnector capacity is fully used.
5. Determine the resulting electricity prices.

3.4 Capacity mechanisms

The main two categories of capacity mechanism that are considered in Europe are versions of capacity markets (including reliability options) and strategic reserves. France is preparing the implementation of a capacity market. In Germany, a small and temporary strategic reserve was implemented recently in the form of reserves that are contracted from Austria in order to compensate for the closure of the nuclear plants in south Germany. In the Netherlands, in 2004 legal arrangements were made for the implementation of a strategic reserve. TenneT, the TSO was assigned with monitoring the generation reserve margin and contracting reserve generation capacity if the margin became too low, but this has not been the case to date so the reserve has not been created. In our model, we explored implementation a strategic reserve in the Netherlands that is relatively larger than the current one in Germany (and also larger than was envisioned for the Netherlands) in order to test its effects in a situation in which neighboring countries also have a capacity mechanism.

The volumes of generation capacity of the involved countries were taken from Eurelectric (2012) for the year 2010 and are fixed in the simulation. The capacity of wind and solar power was set at their percentage average availability according to the IEA (2010). For nuclear capacity in France we use data from RTE (2012), according to which the average volume of nuclear capacity that is dispatched in the French market equals 59.9% of the installed capacity. The resulting baseline volumes of generation capacity are:

- The Netherlands: 23 704 MW;
- Germany: 130 169 MW;
- France: 93 782 MW.

With respect to the long-term effects of the capacity mechanisms, for the sake of the argument we have assumed that the capacity mechanisms have optimal long-term effects and increase the volume of generation capacity. This is an optimistic assumption, as a strategic reserve may suppress investment due to its effect of reducing peak prices. A capacity market is more likely to fully lead to the intended increase in generation capacity, although it may take some time before this is realized. The effects on the volume of generation capacity that we assumed are as follows.

- For Germany, we modeled the current situation in which an additional 1295 MW of reserve capacity is contracted (Bundesnetzagentur, 2012). In the runs with a strategic reserve, this brings total available generation capacity for Germany up to 131 464 MW.
- For the Netherlands, we assumed a strategic reserve of 2333 MW, which corresponds to 10% of the reliable production capacity in 2010. This choice was made in order to evaluate the impact of a large strategic reserve. With this extra reserve, total available generation capacity in the Netherlands is 26 041 MW.
- For France, we assumed that the capacity market would lead to 5913 MW of additional capacity so as to create a capacity margin of 6.3% that allow autonomously covering peak demand in case of soft scarcity as in 2010. The additional capacity bringing total reliable generation capacity up to 99 695 MW.

We assume that a strategic reserve is only dispatched when the supply by market parties, including imports, is insufficient for meeting demand. The dispatch price of the strategic reserve in Germany is set in a way that is similar to Sweden, just above the price of the most expensive unit, an oil powered generation unit. In the Netherlands, the last 10% of generation capacity is dispatched for about 5% of the time. During these hours, the average wholesale electricity price is about 225 Euros/MWh. However, we have assumed a dispatch criterion similar to that in Germany, so the Dutch strategic reserve is dispatched at 100 €/MWh.

In the French capacity market, generation units that underlie capacity credits are dispatched as regular units except when the system is short of capacity. Their price is always equal to the marginal cost of generation; it is assumed that the capacity market effectively prevents physical shortages. In case of a shortage, the units are required to deliver to French consumers at variable cost. We assume that the rules of the French capacity market allow only generators that are located in France to sell capacity credits and only units that have not committed themselves in the capacity market are allowed to export electricity.

The price of the capacity credits is calculated as the absolute value of the difference between producer surplus and total costs of production in a given year, divided by the volume of capacity credits. This implies the assumption that the capacity credit market efficiently provides generation companies with the additional revenues that they need to finance their units without overcompensating them. Again, the absence of market power is assumed. If producer surplus is larger than the total cost of production, the level of payment is zero. The payments are in Euros/MW/year.

3.5 Scenario choices

The demand growth rates that are forecast by ENTSOE for the period 2010-2025 do not lead to scarcity in our model. This may be due to the fact that we do not model network congestion or generator outages, apart from the reduced availability of solar, wind and nuclear power in France. The only risks in the studied countries are of an extreme winter peak in France, like happened last winter, and a limited, regional shortage of generation capacity in southern Germany, which is due to the closure of Germany's nuclear plants in combination with transmission capacity limitations. In order to test the effects of capacity mechanisms, we created extreme demand conditions. They are not likely to occur, but the purpose of capacity mechanisms is to provide a safety net for such extreme situations. In reality, electricity shortages typically occur as a result of a combination of factors such as generator outages, transmission congestion and high demand. For the sake of simplicity, in our model we increased the demand to levels where the capacity mechanisms were necessary. One should therefore not draw conclusions from this model regarding the likelihood of electricity shortages in the future or regarding price expectations; the purpose is to analyze the cross-border effects *if* shortages occur as well as during normal conditions.

A difficulty with creating the scenarios is that in many cases, cross-border capacity is sufficient to mitigate local shortages, while especially the German strategic reserve is so small that under more extreme scenarios its effect is limited in practice and not visible in our model. The reason is that we work with two demand scenarios per case and if the high scenario is too high, the effect of the capacity mechanism is insufficient to prevent a power shortage. In order to obtain our goal of analyzing the cross-border effects we therefore had to change the demand realizations between the different model runs, which has as a disadvantage that the results of the runs are not fully comparable with each other. We made create a baseline run without any capacity mechanism for each scenario as a counterfactual.

<u>Scenario choices for the model runs with a strategic reserve in Germany and an energy-only market in the Netherlands</u>

- **Scenario 1:** low demand in both countries. Demand data for 2010 was used (ENTSO-E, 2012b).
- **Scenario 2:** low demand in the Netherlands, high in Germany. The Dutch demand data for 2010 were multiplied by 1.13, which represents six years of growth at 2.1% per year as forecast by ENTSO-E (2012a).
  To create a high demand scenario for Germany, the load duration curve of 2010 was multiplied by 1.61. Lower values would not cause scarcity in the German wholesale market, partly because of its ability to import electricity from the Netherlands (the cross-border capacity is 3925 MW).
- **Scenario 3:** high demand in the Netherlands, low in Germany. The Dutch load-duration curve for 2010 was multiplied by 1.64 in order to create scarcity. Imports from Germany were sufficient to meet all lower levels of demand.
  Demand in Germany was taken equal to the load duration curve of 2010 multiplied by 1.08 (which corresponds to six years of cumulative growth at a 1.4% per year growth rate, as forecast by ENTSO-E (2012a)).
- **Scenario 4:** high demand in both countries. High demand in the Netherlands was taken as the load duration curve of 2010 multiplied by 1.45 and for Germany was taken as the load duration curve of 2010 multiplied by 1.56 (cumulative demand growth for no year in specific). Lower demand values were chosen than the scarcity values in Scenarios 2 and 3. The reason was to analyze the case in which scarcity in Germany call the activation of strategic reserves and at the same time scarcity in the Netherlands results in the imports of excess power produced with the reserve units in Germany. Since the strategic reserve in Germany is small, higher combined demand in the two countries would have led to an absolute shortage in the model.

Table 2: Annual average and peak demand (MW) in the scenarios for the runs with the Netherlands and Germany

	Scenario	1	2	3	4
Netherlands	average	13 706	15 526	21 152	19 999
	peak	18 096	20 499	27 928	26 405
Germany	average	68 131	109 929	74 058	106 919
	peak	83 345	134 477	90 595	130 795

Scenario choices for the model runs of France and the Netherlands

- **Scenario 1:** low demand in both countries. For the Netherlands, demand data for 2010 from ENTSO-E(2012 b) was used. For France, the load duration curve for 2010 multiplied by 0.88. As production capacity was tight, a lower demand value was used in the model to create a situation without scarcity in France.
- **Scenario 2:** low demand in the Netherlands and high demand in France. The Dutch demand data for 2010 were multiplied by 1.13, as described above. For France, the load duration curve of 2010 was multiplied by 1.04. At this level of demand there is an absolute power shortage in France (even when imports from the Netherlands are maximal) in the scenario without a capacity mechanism. Also in the presence of the extra reserve margin that is created by the capacity mechanism there is a small shortage.
- **Scenario 3:** high demand in the Netherlands, low demand in France. Dutch demand was created by multiplying the load duration curve of 2010 with 1.332. Demand in France was taken as the values of the load duration curve of 2010 multiplied by 0.919. This value represents higher demand in France than in Scenario 1, but still is low enough that the French system is not tight.
- **Scenario 4:** high demand in both countries. Demand in the Netherlands was taken as the load duration curve of 2010 multiplied by 1.37. Demand in France was chosen as the load duration curve of 2010 multiplied by 0.97. A higher demand scenario was chosen for the Netherlands and a lower one for France, compared to Scenarios 2 and 3. The reason is that larger values of demand (peak) in the Netherlands demonstrate the consequence of the withholding of the French generation capacity that is committed in the capacity market.

Table 3: Annual average and peak demand (MW) in the scenarios for the runs with the Netherlands and France

	Scenario	1	2	3	4
Netherlands	average	13 706	15 526	18 262	18 898
	peak	18 096	20 499	24 112	24 952
France	average	56 727	66 764	58 863	62 522
	peak	86 683	102 019	89 947	95 538

4 Results

4.1 Strategic reserve in Germany

The strategic reserve in Germany can help to avoid shortages and associated high prices in Scenarios 2 and 4 (when capacity is tight in Germany). See Figure 3. However, the results are highly sensitive to the choice of scenario. If total demand in the interconnected countries is slightly lower, the reserve is not needed, either because Germany has sufficient generation capacity or because it can import enough capacity. If demand is slightly higher, a power shortage results despite the presence of the reserve and high scarcity prices result.

The German strategic reserve only has an effect on electricity prices in the Netherlands when both countries face a shortage. Then the reserve contributes to lower prices in the Netherlands as well, as long as the reserve is large enough to avoid a shortage in the two markets together. This suggests that the effect of the reserve 'leaks' away across the border, but the effect on the German price is small in our model. The reason is the step-wise representation of supply: as long as the export demand does not cause the next step in the supply function – the next technology – to be dispatched, the electricity price does not change substantially. However, in case of a regional shortage, the effect of leakage will be that generation supply, including the reserve, will be exhausted sooner.

The generators who provide the reserve capacity earn € 40,791 per MW per year. This payment is independent of the electricity prices, as the reserve is dispatched at variable cost and therefore needs to be paid its fixed cost. We assume that the reserve payments will be determined in a competitive process and therefore will be sufficient to remunerate the costs of the reserve. However, a concern about a strategic reserve is that it may suppress investment. The model is optimistic, in that the reserve is added to existing capacity and no (old peak) generators were closed as a result of the lower prices that are caused by the reserve. In order to test whether the reserve would really not suppress investment or displace existing capacity, a more detailed dynamic model of wholesale costs and prices should be developed.

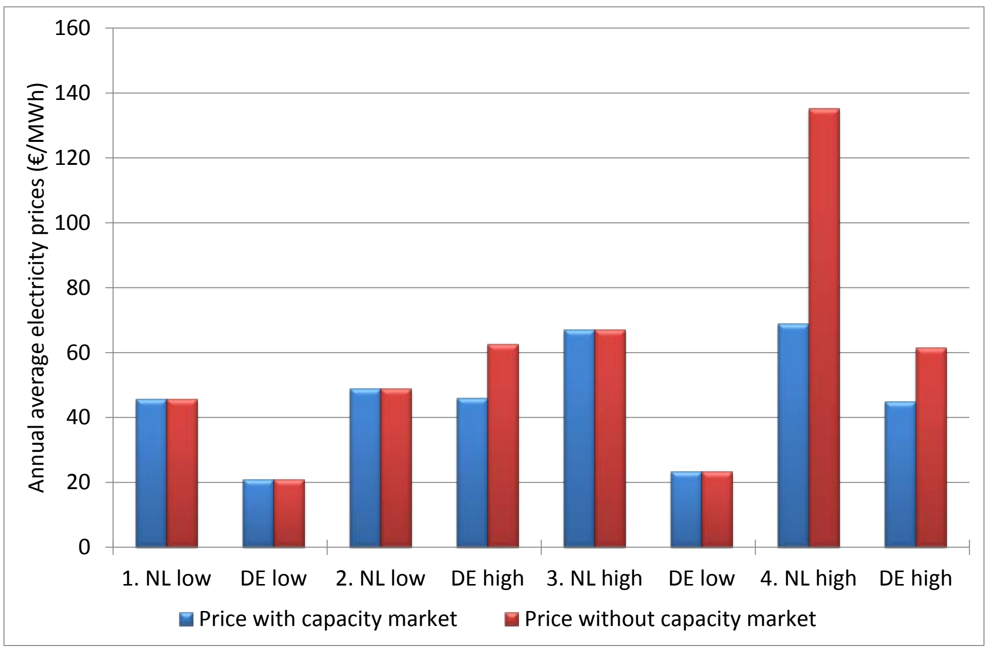

Figure 3: Annual average wholesale prices in the Netherlands and Germany with (blue) and without (red) a strategic reserve in Germany for combinations of low and high demand scenarios in both countries

4.2 Capacity requirements in France

Figure 4 shows that the capacity market in France largely mitigates shortages in France in our scenarios. Importantly, if there is an electricity shortage, the price effects are limited. While the size of the additional capacity is modest, at about 6% of installed capacity, it is large enough to make France self-reliant in our scenarios. Due to the additional generation capacity, scarcity prices are less frequent. This reduces average electricity prices in the French wholesale market. Note that the counter-intuitive result in Figure 4 that prices in France are higher when there is sufficient capacity in the Netherlands than when there is a shortage in the Netherlands is due to the differences in scenarios. The reason is that in Scenario 2 demand in France had to be very high in order to produce a shortage – given the additional generation capacity due to the capacity market.

The French generators are compensated for these lower prices by the revenues that they earn from selling capacity credits. We assumed that the capacity market produces equilibrium prices that, together with the revenues from selling electricity, are enough to fully remunerate generators: we assumed that the capacity payments are the difference between the generators total annual cost and their operating profits. Therefore the capacity payments are highest when demand is low in both countries and there are no price peaks (Scenario 1). In this case, the capacity credit price is equal to € 75 334 per MW per year, which happens to correspond to the fixed cost of gas plant. When electricity prices are higher, the capacity payments are correspondingly lower, so total generator revenues remain close to cost. When there is a shortage in the Netherlands but not in France, the French generators earn extra revenues from the exports. Subsequently, the price of a capacity credit falls to € 46 169 per MW per year.

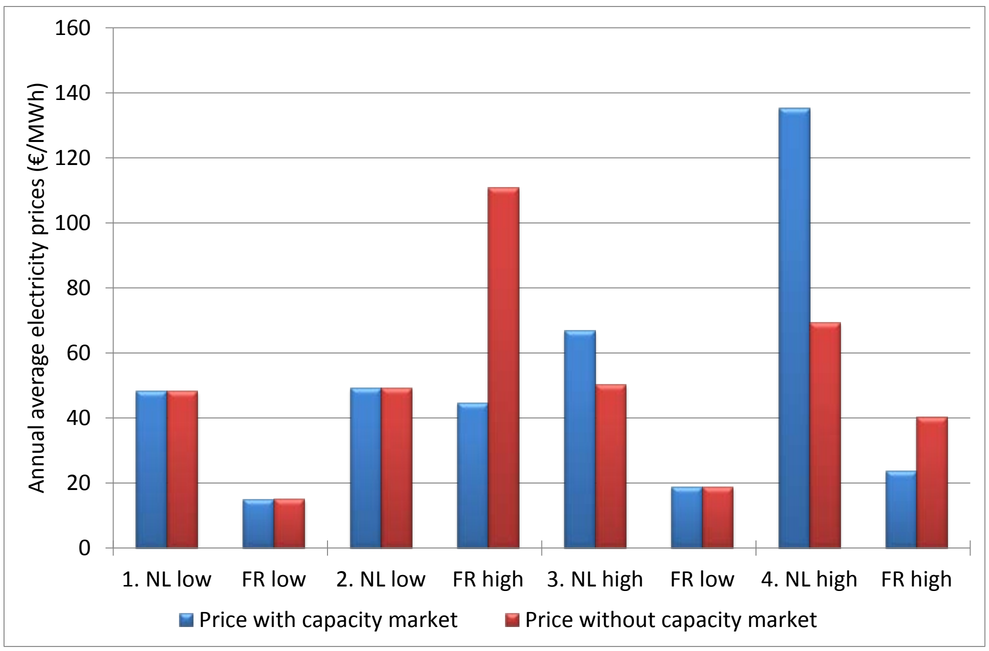

Figure 4: Annual average wholesale prices in the Netherlands and France with (blue) and without (red) a capacity market in France for combinations of low and high demand scenarios in both countries

The capacity credit price falls further in our model in a year with shortages, as the higher electricity prices pay for most or all the cost of generation. In reality, it is more likely that the capacity market is also short and the price of capacity credits rises to the level of the penalty which consumers would have to pay for not having enough capacity credits. Combined shortages in the capacity market and the electricity market would produce high incomes for generation companies, but if the capacity requirement is large enough this scenario is unlikely.

The French capacity market has an effect of increasing peak prices in the Netherlands. When both countries are short of capacity, we assume that France does not allow the generators who have sold capacity credits to export their electricity. As a result of the reduction in imports, prices in the Netherlands increase. A solution could be to allow French generators to export to the extent that it does not affect the security of supply within France. The capacity market could also suppress incentives for demand response, as in a regional power shortage it would keep prices artificially low in France. A solution to this problem is to allow demand reduction to sell capacity credits, as is done in PJM in the USA. Only verifiable demand reduction could qualify, however, which means that in practice mostly large industries would participate.

In the long run, a risk would be is that imports from France to the Netherlands would discourage investment in the Netherlands while these imports would not be available when capacity is tight in France. In theory, the resulting high price spikes in the Netherlands should attract sufficient investment, but it is the question whether this will be realized, as these peak units would have few expected operational hours. At the same time, the exports of electricity from France reduce the price level of the capacity credits that the French generators need to recover their costs.

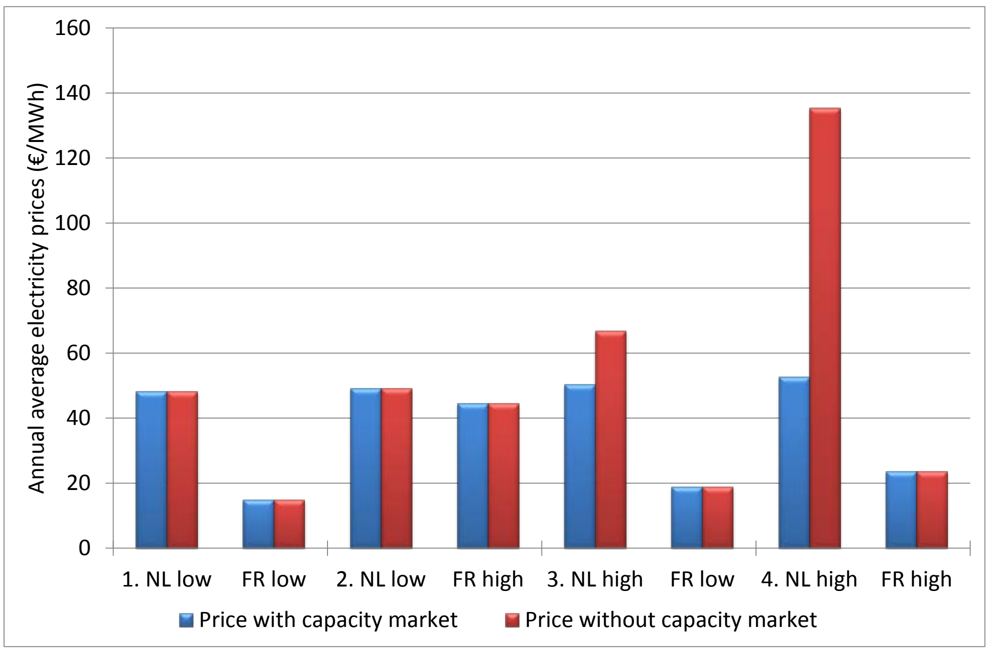

Figure 5: Annual average wholesale prices in the Netherlands and France with (blue) and without (red) a strategic reserve in the Netherlands for combinations of low and high demand scenarios in both countries. In all runs, a capacity market in France is modeled.

4.3 Strategic reserves in the Netherlands and capacity requirements in France

In order to avoid the disadvantage of the implementation of a capacity market by a neighboring country, the Netherlands could implement a capacity mechanism itself. As the regulations for implementing a strategic reserve have already been implemented in the Netherlands, we modeled a strategic reserve of 10% of the reliable generation capacity in combination with a capacity market in France. As the results in Figure 5 show, this is an effective strategy for stabilizing wholesale electricity prices, both when there is a shortage in the Netherlands alone and when both countries are short.

Imports from France remain the same, as the cost of electricity in France in lower. The Netherlands would have to pay the providers of the strategic reserve for the fixed cost of peak plant, in the order of €55 000 per MW per year. These payments may appear high in comparison with the prices of the capacity credits in France, but they only apply to a small share of generators.

Because France does not import electricity from the Netherlands, this case effectively pertains to an strategic reserve in an isolated country. This, plus the fact that the reserve represents a much larger fraction of demand, are the reasons that the reserve is more effective in stabilizing prices. (What the results do not show is that this larger reserve is effective in a wider range of scenarios than we presented.) However, in practice the benefit of the reserve may leak away from the Netherlands to Germany, Belgium, Norway or the UK. Moreover, earlier research showed significant other disadvantages of a strategic reserve, such as the risk of price manipulation and investment cycles (De Vries and Heijnen, 2008; De Vries, 2007).

5 Generation adequacy in Europe

The arguments concerning capacity mechanisms play out differently in the different European countries as a consequence of their generation portfolios and past market performance. In Scandinavia, concerns about years with low hydropower availability were a reason for the implementation of strategic reserves. In southern Europe and Poland, capacity payments were implemented shortly after liberalization, apparently due to concerns about insufficient investment. In Germany, the Netherlands, Belgium Austria, the UK and France, among others, implementation of a capacity mechanism was not considered necessary.

Given the reality of different capacity mechanisms in different countries, in this paper an analysis is presented of the possible side-effects of this lack of harmonization. The intention is not to make a normative argument in favor of one single generation adequacy policy; different conditions may well warrant different policy instruments. However, whereas the merits of capacity mechanisms are typically evaluated for a closed system, most European countries have open markets and the effects on trade can be significant.

The capacity mechanisms have fundamentally different effects on trade between countries. A strategic reserve has no effect as long as it is not called upon; when it is, it tends to lower prices. To the extent that there is interconnector capacity, the price reduction could be exported to neighboring countries. This means on the one hand that the reserve is less effective in improving the margin between supply and demand in the country in which it is implemented, which means that the consumers who are paying for it do not get their full value. On the other hand, the neighboring countries – if they do not have some form of capacity mechanism themselves – may be faced with lower peak prices (or the expectation thereof) which may discourage investment in these countries. Ideally, a strategic reserve should be implemented in the entire relevant market.

Capacity markets and reliability options are characterized by very different dynamics. If they are designed well (which is not trivial), they provide a hedge against high prices to the consumers in the country in which they are implemented. When there is a regional shortage, the consumers are protected by a price cap (in a capacity market) or have a financial hedge against high prices (in case of reliability options). Both instruments should facilitate sufficient investment in generation capacity physical shortages of electricity become extremely rare. During the times when the capacity is not called (because there are sufficient reserves), however, this additional generation capacity may be exported and will likely depress regional electricity prices. In the country with the capacity market, the generation companies are compensated through the revenues from selling capacity credits or reliability options, but the generation companies in neighboring energy-only markets will experience the additional competition without the additional revenues. This will put pressure on these countries to also introduce a capacity mechanism. The extent of this effect depends on the shape of the supply functions in the different countries (so, on the generation portfolios) and on the extent of transmission (interconnector) congestion.

The long-run effects of different capacity mechanisms in different countries are uncertain. Here we assumed that capacity mechanisms indeed lead to more investment, but there are good reasons to believe that a strategic reserve does not do this to the full extent that was assumed here. Capacity markets are more effective in this respect, but may also have stronger negative externalities on neighboring countries. We did not model multilateral effects which are likely to occur in Europe's meshed transmission network. We also left Belgium out of the analysis. Because generation capacity in Belgium is tight, it would not improve regional generation adequacy and therefore not change the analysis by much. Other countries, however, could deliver peak capacity to the three countries in our analysis, especially the Alp countries and Norway. Improved demand price-elasticity could mitigate the effects of intermittent generation on wholesale prices, reducing the need for back-up capacity.

The basic dilemma between a strategic reserve, which is easy to implement but may distort the wholesale market and actually discourage some investment, and a capacity market or reliability options, which are complex instruments with much room for regulatory failure, is complicated by the cross-border effects of both mechanisms. In the long term, capacity subscriptions may be more attractive, but this instrument has not been demonstrated and requires a smart meter for every connection (cf. Doorman, 2000; De Vries, 2007).

6 Conclusions

As the share of intermittent resources is increasing in Europe, the case for implementing a capacity mechanism is gaining weight. The debate is complicated, however, by the fact that a number of European countries have already implemented various kinds of capacity mechanisms, while in the middle of Europe a zone remains of countries do without capacity mechanisms. Capacity markets appear to be more effective than strategic reserve in attracting investment and securing supply in the long run, but may discourage investment in neighboring countries. A strategic reserve is easier to implement and does not have this negative externality, but its dynamic effectiveness is less certain and its effect may leak away across the border.

The negative externality of a capacity mechanism may put pressure on neighboring countries to also implement a capacity mechanism. However, the proliferation of different types of capacity mechanisms – every category of capacity mechanism can be implemented in a myriad of different ways – creates a significant risk trade between countries will be increasingly distorted. Considering also the regulatory uncertainty that is brought about by this process and the risk of regulatory failure with implementing the more sophisticated capacity mechanisms such as capacity markets and reliability options, the positive effect on investment is not a given.

In the long run, a system of capacity subscriptions appears more attractive than the current capacity mechanisms, as it is independent of wholesale market design, less complex and intrusive than reliability options or a capacity market and closest to an unregulated market design. Issues that were not considered in this study and which warrant further investigation are the possible effects of oligopolistic behavior in interconnected markets with different capacity mechanisms (and possibly with companies who are active in multiple of these interconnected markets) and the dynamic behavior of these markets.

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